# Transportation of Severely Curved Canals: Comparison of One Shape and K3 Rotary Systems

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## Abstract

**Background and Objectives:** This study sought to compare canal transportation and centering ability of One Shape and K3 rotary systems in preparation of severely curved mesiobuccal root canals of human mandibular first molars using cone beam computed tomography (CBCT). **Materials and Methods:** In this in vitro, experimental study, 40 mandibular first molars extracted for periodontal reasons were divided into two groups of root canal preparation with One Shape and K3. CBCT scans were taken before and after instrumentation to assess canal transportation and the centering ratio at 2 (apical third), 5 (middle third) and 8 (coronal third) mm from the apical foramen. **Results:** Data analysis showed no significant difference in canal transportation between the two groups in the middle (5 mm) and coronal (8 mm) thirds ($p>0.05$). However, in the apical third (2 mm), canal transportation by K3 was significantly less than that by One Shape ($p<0.05$). **Conclusion:** Canal transportation was less in the apical third by use of K3 compared to One Shape. Also, the canal centering ability of One Shape was less than that of K3. However, the two systems were not significantly different in the middle and coronal thirds.

**Keywords:** Canal transportation; Canal centering; K3 rotary system; OneShape; Cone-beam computed tomography

## Introduction

Root canal cleaning and shaping is an important step in root canal treatment, aiming to mechanically enlarge and shape the root canal and eliminate microorganisms via chemical debridement of the root canal system. [1,2]

Cleaning and shaping of curved root canals are more difficult since all endodontic files tend to deviate from the main root canal path and straighten up. [3] Despite the introduction of new techniques and tools for instrumentation of curved root canals, clinicians still try to minimize procedural errors such as ledge formation, apical transportation and loss of working length. [4] Canal transportation occurs when dentin is excessively removed from the external wall of the curvature in the apical third and internal wall of the curvature in the coronal third of the canal. Thus, root canal dentin is excessively removed in some parts of the root canal. [1]

Canal transportation results in excessive removal of dentin and ledge formation in canal wall. [5] As the result, some debris and microorganisms may remain in the canal. [4] Moreover, it negatively affects the obturation quality. [6] A transported canal has less resistance against forces applied to condense gutta-percha. As the result, gutta-percha would have inadequate density, or over-extension of root canal filling material may occur into the periapical region, increasing the risk of treatment failure. [1]

During root canal preparation with stainless steel files, deviation from the main canal path may occur. [6] Although several techniques have been introduced to prevent canal transportation, nickel-titanium (NiTi) rotary systems are preferred to maintain canal shape and centering. [3] Introduction of rotary NiTi files enabled easier and safer preparation of root canals with complex anatomy. [7] Rotary NiTi files straighten the canal in a less extent and have higher centering ability in severely curved canals. [5] Recently, the use of rotary NiTi files has increased due to their safety, easy canal shaping and less iatrogenic errors in severely curved canals. [4] Other advantages of rotary NiTi files include their easier use and faster canal preparation. [8] Many rotary files prepare the canal using the crown-down technique. In this method, smaller file sizes are consecutively used to reach the apex. [1]

Rotary files have different cross-sectional designs, cutting edges, helical angle, flute number and tip design. Manufacturers have attempted to design files with maximum flexibility, high fracture strength and a strong cutting blade. [9] It has been shown that the design and manufacturing process of rotary files significantly affect their clinical performance. [8] One Shape is a single file system, which is used with rotational movement in a clockwise fashion. The file has a unique design and variable cross-section along the file length. This property increases the optimal cutting surface of each file in the canal. Also, electropolishing has been performed to increase the cutting surface. This system includes one instrument with #25 file tip size and 0.06 taper. This file should be discarded after use for one tooth and can be used maximally for four canals. Sterilization of files damages the cutting surface. [10]

K3 is another rotary system with variable cross-section and variable peach along the file length. This unique design minimizes procedural errors during root canal preparation. [11] K3 file has a U-shaped cross-section. These files have three radial lands with 45° rake angle.



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Considering the density and stiffness of dentin, files with a positive rake angle are more effective than those with a negative rake angle and require less energy for dentin removal. [12] K3 file has excellent cutting efficiency and large radial land, which increases the file strength and centering ability when used in the canal. Their non-cutting tip further adds to their flexibility in curved canals. [13] The central core of this file has a variable diameter, which further adds flexibility to the file. Asymmetric lands have different widths. Also, a flute of these lands has variable depth and width. [14]

Several methods are used to evaluate the quality of instrumentation including light microscopy, electron microscopy, photography, radiography, a prefabricated model of the canal and computerized systems. [15] Computed tomography (CT) and micro-CT were first suggested for this purpose since they are non-invasive, do not require tooth sectioning and have the ability to reveal canal morphology. [16] Cone-beam computed tomography (CBCT) was later suggested for this purpose since it does not require tooth sectioning and is reproducible. [1] CBCT has been previously used to quantify the amount of dentin removed. [17,18] Using CBCT, the exact anatomy of the root canal system can be revealed. [19,20] and CBCT has been confirmed to be an accurate tool to study the root canal anatomy. [21]

Despite the advantages of NiTi rotary files, their use is time consuming due to the high number of files in K3 and ProTaper systems. The current treatment approach emphasizes using the least number of files. [22,23] In some single file systems like One Shape, only one file is used for canal preparation. This study aimed to compare canal transportation caused by the use of One Shape single-file and K3 multiple-file rotary systems.

## Materials and Methods

This in vitro, an experimental study was conducted on 40 mesiobuccal canals of extracted mandibular first molars. The teeth had been extracted due to hopeless periodontal prognosis. The study was approved in the ethics committee of Kermanshah University of Medical Science (code:KUMS.REC.1394.150). The Sample size was calculated to be 40 canals using Minitab software assuming alpha=0.05 and beta=0.2. The teeth were cleaned of soft tissue debris and calculus and were disinfected with 2.5% sodium hypochlorite solution. The inclusion criteria were the absence of external root resorption, the absence of severe caries extending to the root, absence of root cracks and mature apex. The teeth were then stored in 10% formalin to remain hydrated during the study period. [24]

Access cavity was prepared using a bur and high-speed handpiece. Canal orifices were negotiated using a #10 K file (Dentsply Maillefer, Ballaigues, Switzerland). Teeth with completely separate non-calcified canals (Vertucci’s type IV) were chosen. [25] A radiograph was obtained in buccolingual direction using a parallel technique. Tooth root was outlined on a tracing paper and the degree of canal curvature was determined using the Schneider’s method. [26] Teeth were 20-40° curvature were chosen. Canal length was measured under a microscope using a #10 K-file. Tooth crowns were cut at 17 mm distance from the apex and working length was determined 1 mm short of this length. Thus, working length in all teeth was 16 mm. [13] The canals were randomly divided into two groups (n=20) and mounted in a mounting jig made of acrylic resin. Before mounting the teeth in acrylic resin, the root ends were covered with putty to simulate the periodontal ligament. A Jig was used to ensure reproducibility of CBCT scans.

All teeth were mounted in four jigs. A piece of metal in the form of an arrow was also mounted in each jig to standardize the scanning position before and after instrumentation. CBCT scans were then obtained. [24] CBCT scans were obtained in high-resolution mode, 8 × 11 cm field of view and human mode (NewTom, Verona, Italy).

Root canal instrumentation in each group was performed according to the manufacturers’ instructions. In group 1, canals were cleaned and shaped using One Shape rotary file system (Micro-Mega, Besancon, France) such that after preparing a glide path using #10 and #15 K-files, orifice shaper was used. Next, #25 file with 6% taper was used to two-thirds of the canal with in-and-out movement. A #10 K-file was used to remove debris and rinse the canals. The file was reached to 3 mm of the working length, retracted and the same previous steps were repeated. Next, the file was reached to the working length operating at 400 rpm with 4 Ncm torque. Each file was used for three canals.

In group two, canals were instrumented using K3 rotary system (SybronEndo, Orange, CA, USA). After preparing straight access to the orifice and maintaining patency using a #10 K-file, #25 file with 10% taper and #25 file with 8% taper were used for the preparation of the coronal third. Then, #15 hand file was used to the working length and then #35 file with 6% taper, #35 with 4% taper and #25 with 6% taper were used, respectively. If working length was not reached after using the final rotary file, according to the manufacturer’s instructions, #20 rotary file with 4% taper was used. Each file was used with five pecking motions and the canal was rinsed prior to using the new file. This rotary system operated at 350 rpm and 3 Ncm torque. The file was changed as soon as resistance was felt in the canal. After each time of use, the canal was rinsed with sodium hypochlorite. Each file was used for five canals. Both rotary systems were used with Endo-Mate (NSK, Nakanishi Inc., Tokyo, Japan).

CBCT scans were taken again of all samples and the data were recorded in a computer. Canal transportation was determined using the formula (A1-A2)-(B1-B2) where A1 is the shortest distance from the external wall of the mesial root to the internal wall of the uninstrumented mesial canal; A2 is the shortest distance from the external wall of the mesial root to the internal wall of the instrumented mesial canal; B1: is the shortest distance from the external wall of the distal part of the root to the internal wall of the distal part of uninstrumented canal and B2: is the shortest distance from the external wall of the distal part of the root to the internal wall of the distal part of instrumented canal. [27]

To assess centering ratio, the following formula was used. [27]

CR=(B1-B2)/(A1-A2) or CR= (A1-A2)/(B1-B2)

Selection of the formula should be done in a such a way that figure in the numerator should be equal to or smaller than the denominator. Thus, the result would always be a value between zero and one. To measure and compare dentin thickness on scans before and after instrumentation, NNT Viewer version 2.21 (Quantitative Radiology, Verona, Italy) was used. Axial images were shown on a monitor. The first point where the canal was completely surrounded by dentin was considered as apical foramen. The same was done for post-instrumentation scans. To measure dentin thickness on CBCT scans, maximum magnification (400%) was used. Measurements were made on slices at 2 mm, 5 mm and 8 mm from the apical foramen. [6] The Degree of canal transportation and centering ratio were determined separately at each distance [Figure 1].

Data were analyzed using SPSS version 18 (SPSS Inc., IL, USA). Since data were not normally distributed (confirmed by Kolmogorov-Smirnov test), canal transportation and centering ability were compared between the two groups using the Mann Whitney test. Level of significance was set at 0.05.

## Results

### Canal transportation

Table 1 shows the mean canal transportation in the two groups at 2,

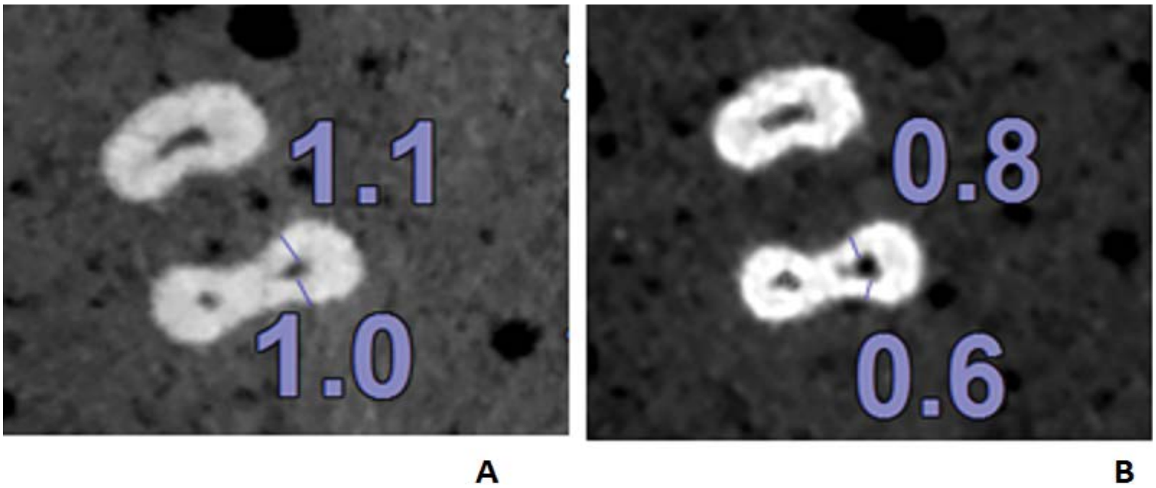


**Figure 1:** Measurement of distance from the mesial and distal root surface to the internal canal wall in uninstrumented (A) and instrumented (B) canals.

**Table 1: Mean and standard deviation of canal transportation in the two groups at 2, 5 and 8 mm from the apex.**

| Distance from apical foramen | Apical (2 mm) | | Middle (5 mm) | | Coronal (8 mm) | |
|---|---|---|---|---|---|---|
| | Mean | Standard deviation | Mean | Standard deviation | Mean | Standard deviation |
| One Shape | 0.1400 | 0.1046 | 0.1000 | 0.0794 | 0.1500 | 0.1051 |
| K3 | 0.0750 | 0.0550 | 0.0650 | 0.0587 | 0.0900 | 0.0640 |
| *P* value | 0.026 | | 0.155 | | 0.054 | |

**Table 2: Mean centering ratio in the two groups at 2, 5 and 8 mm from the apex.**

| Distance from apical foramen | Apical (2 mm) | | Middle (5 mm) | | Coronal (8 mm) | |
|---|---|---|---|---|---|---|
| | Mean | Standard deviation | Mean | Standard deviation | Mean | Standard deviation |
| One Shape | 0.59737 | 0.21201 | 0.71667 | 0.20305 | 0.63667 | 0.23986 |
| K3 | 0.73246 | 0.20142 | 0.77500 | 0.20785 | 0.69167 | 0.21646 |
| *P* value | 0.035 | | 0.414 | | 0.495 | |

5 and 8 mm from the apex. Comparison of canal transportation in the apical third between K3 and OneShape showed significantly less apical canal transportation in K3 group (p=0.026). The mean canal transportation was not significantly different in the middle (p=0.155) and coronal thirds (p=0.054) between K3 and OneShape.

### Centering ratio

Table 2 shows the mean centering ratio in the two groups at 2, 5 and 8 mm from the apex. Comparison of centering ratio in the apical third of the two groups showed a significant difference and K3 caused significantly less apical transportation (p=0.035). The difference in this regard between the two groups was not significant in the middle (p=0.414) or coronal (p=495) thirds.

## Discussion

This study assessed the canal transportation rate and centering ability of One-Shape and K3 rotary systems for preparation of mesiobuccal root canal of human mandibular first molars with severe curves using CBCT. Data analysis showed no significant difference in canal transportation between the two groups in the middle (5 mm) and coronal (8 mm) thirds (p>0.05). However, in the apical third (2 mm), canal transportation by K3 was significantly less than that by OneShape (p<0.05).

Canal preparation is performed aiming to create a conical canal with an appropriate taper for efficient filling.[11] Procedural errors such as ledge formation and transportation may occur during root canal preparation. Factors affecting the occurrence of procedural errors include complex canal anatomy, the cross-sectional design of the instrument, not following the proper sequence of instruments, an experience of the operator, rotational speed and insufficient use of irrigating solutions and lubricants.[28] Despite the introduction of new root canal preparation methods, instrumentation of curved canals is challenging for clinicians due to higher risk of ledge formation, apical transportation and working length loss.[4]

The American Association of Endodontists defines canal transportation as removal of root dentin from the external wall of the curve in the apical half of the canal due to the inherent tendency of the file to return to its original straight shape.[11] All endodontic files are primarily made of a straight hard metal wire. Thus, stresses are not uniformly transferred to the contact area of instrument and canal. Straight instruments introduced into the canal tend to straighten up in the canal and thus, apply a greater load to the external wall of the canal curvature; resultantly, transportation occurs.[29] Apical transportation over 0.3 mm can affect the outcome of endodontic treatment because it significantly decreases the seal of filling material.[30]

Several methodologies are used for assessment of centering ability of NiTi files such as plastic models, histological sections, scanning electron microscopy, radiographic comparison, serial sectioning, silicon impression making from an instrumented canal, CT, micro-CT and CBCT.[31] CBCT is a high-resolution scanning system suitable for clinical use in endodontics for determination of canal morphology, fracture and changes following canal instrumentation. The radiation dose of CBCT is less than that of micro-CT but it has a lower spatial resolution, which can cause problems during enhancement. Using high-resolution CT, the higher number of scans can be obtained from samples. Micro-CT is only suitable for use *in vitro* while CBCT is extensively used *in vivo*.[4]

Our results showed that canal transportation by One Shape was significantly greater than that by K3 at 2 mm distance from the apex but no significant difference was noted between the two systems at 5 and 8 mm from the apex. K3 better preserved the canal curvature.

Schafer and Florek [32] compared Flexofile hand file, stainless steel files, and K3 rotary system and showed that K3 file better-preserved canal geometry. They concluded that K3 file cleans the curved canals faster and with minimum transportation towards the external wall of the curvature. Bergmans et al. [33] compared K3 rotary files with constant taper and ProTaper files with a progressive taper in terms of change in canal curvature and dentin removal and found no significant difference between the two systems in terms of canal transportation and centering ability. They indicated that files with progressive taper are less affected by the canal curvature and apical preparation is performed more efficiently by use of these instruments. The two systems had no significant difference in terms of canal transportation; although ProTaper caused slightly greater canal transportation in the coronal third.

Ayar and Love [34] compared shaping the ability of Profile and K3 systems in curved canals (20 and 30°). Dentin removal by both files was greater from the external wall of the curvature. They indicated that both rotary systems were capable of proper root canal shaping with minimal canal transportation. Al-Omari et al. [14] reported that the K3 system compared to Profile caused significantly less canal transportation. Based on the results of Akhlaghi et al, [35] K3 rotary system better maintained the original canal path and caused significantly less canal transportation than ProTaper. Oliveira et al. [13] discussed that K3, K-flexofile, and NiTiFlex were not significantly different in terms of canal transportation. [13] Madani et al. [36] found no significant difference between K3 and K-Flexofile and reported that both systems caused minimal canal transportation. Cai et al. [37] compared K3 and Hero 642 and found no significant difference between the two systems in terms of canal transportation. In the study by Zhao et al, [9] Twisted File showed less canal transportation than K3 and this difference was significant. El-Batouty and Elmallah [12] indicated that the Twisted File caused less canal transportation than K3. Agarwal et al. [11] compared ProTaper, One Shape, and WaveOne and showed that ProTaper caused significantly greater canal transportation in the coronal third but the three systems showed the minimal difference in the middle and apical thirds. Burklein et al. [38] reported that One Shape caused significantly less canal transportation in the middle and apical thirds compared to WaveOne and Reciproc. Deepak et al. [39] compared OneShape, ProTaper and Revo S and found no significant difference in canal transportation among the three but Revo S was slightly superior to the other two systems. Capar et al. [40] compared Oneshape, ProTaper Universal, ProTaper Next X2, Twisted File, WaveOne and Revo S and found no significant difference among the systems in terms of canal transportation. Different rotary systems show variable behaviors in canals with variable degrees of curvature. Thus, in severely curved canals, special attention must be paid to file properties.

K3 files have three radial lands and therefore, have unique properties. K3 file remains at the canal center during rotation, and therefore, preserves the canal curvature. File tip also affects the centering ability. Non-cutting tips preserve the internal canal curvature. [4] These two systems have non-cutting tips; thus, this parameter was the same in both systems in our study.

In K3 files, the file has less traction into the canal due to changed torsional angle and variable peach along the file length; this may also explain better-centering ability of K3 system. Also, K3 files are available in different sizes and tapers and thus, as soon as resistance is felt, the clinician can switch to a smaller size. This further maintains canal curvature and reduces the risk of canal transportation.

No significant difference in the middle and coronal thirds between the two systems in our study can also be due to the unique property of One Shape. The cross-sectional design of the file tip has three cutting blades, which further remove dentin while in the middle and coronal sections, the cross-section of the file has two cutting blades. This unique property can explain the significant difference in the apical region. Thus, K3 rotary file is more suitable than One Shape for maintaining the primary curvature of the canal. This study had an *in vitro* design and suffered the limitations of *in vitro* studies. There are numerous confounding factors in the clinical setting that cannot be simulated in vitro. Future clinical studies are required to find more reliable results. Also, other procedural errors must be assessed and compared among different rotary systems.

## Conclusion

Within the limitations of this study, the results showed that One Shape caused greater canal transportation in the apical third while the two systems were not significantly different in the middle and coronal thirds. K3 system showed higher canal centering ability than One Shape and therefore, K3 is safer than One Shape for use in severely curved canals.

## Conflict of Interest

The authors disclose that they have no conflicts of interest.

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